Small Animal Pacemaker

Conceptual Design and Options Considered

Group SD1305

Kassandra Almen, Courtney Becker, Gage Bickler, Jared Hansen

Advisors: Dr. Ewert and Dr. Glower

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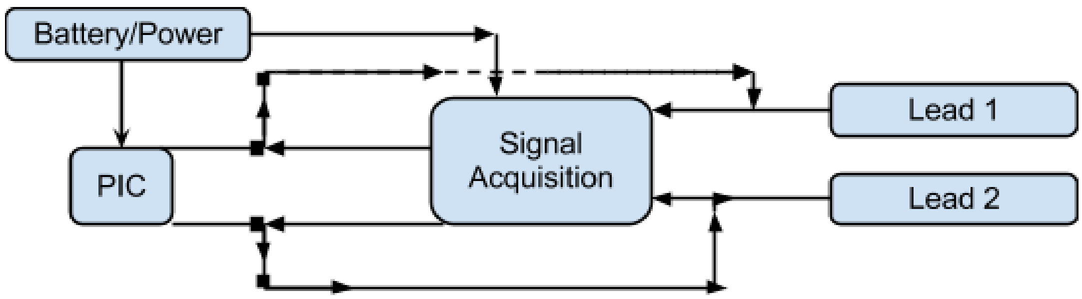
Introduction:
The pacemaker is a medical device that is used to regulate the beating of the heart by using electric pulses that are transported from the body of the device to its leads. The leads are attached to an atrium and a ventricle. These electrodes have the ability to sense the electric signal from the connected area; if the pacemaker detects an inadequate signal, correct pacing voltage can be applied. There is a nomenclature used to define the type of pacemaker called the "Three Letter Pacemaker Designation." The first letter designates the chamber that is being paced: A for atrium, V for ventricle, and D for both. The second letter designates the chamber that is being sensed: A for atrium, V for ventricle, and D for both. The third designates the type of pacing: T for trigger mode, I for inhibit mode, and D for both. Trigger mode is defined by a device that always paces, while inhibit mode paces only when the pace is needed. The animals that this device will be implanted into are called knockout mice. These knockout mice are genetically engineered to have a gene altered with one that causes heart disease. The pacemaker would control the hearts and act as a cardiovascular research device. This project was suggested and advised by Dr. Jacob Glower and Dr. Daniel Ewert of the NDSU ECE Department.

Previous Work:
There currently are no existing patents for small animal pacemakers, however there are patents on miniaturized pacemakers. There are also several patents pertaining to varying lead types, biological pacemakers, battery and non-battery operated pacemakers, and internal and external pacemakers.

- *Heart rate adjusting devices*
    - Non-electrode-lead ultra-thin micro multifunctional heart rate adjusting device
        - Inventors: Luyi Sen
        - Patent filed Feb 15, 2008
- *Small animal pacemakers*
    - Igor Efimov of Wash Univ in St. Louis
- *Leads*
    - Implantable pacemaker lead
        - Inventors: John R. Helland, Hong Li
        - Patent filed Oct 16, 1996
    - Pacemaker lead with enhanced sensitivity
        - Inventors: Benjamin D. Pless, James E. Sluetz, Paul R. Spehr
        - Patent filed Dec 18, 1985

Design Options and Selected Approach:

Shown below is the block diagram of our pacing device. Using this, we can consider what parts we need to satisfy each block.



- **Power**
  - *BR-425/BN Battery*
    - Advantages
      - Small size (4.2mm x 25.9mm)
      - Lead-free (RoHS compliant)
      - 3 volt rating
    - Disadvantages
      - 25mAh capacity at 500μA discharge rate allows only approximately 50 hours of battery life
      - Cylindrical shape does not have ideally small surface area
      - Non-rechargeable
  - *BR-1225/VCN Battery*
    - Advantages
      - Smaller surface area than BR-425/BN (12.7mm x 3.6mm x 14.7mm)
      - 48mAh capacity at 30μA discharge rate ~ 2 month battery life
    - Disadvantages
      - Rounded shape can be difficult to fit
      - Non-rechargeable

- **Microprocessor**
  - *PIC10F200T-I/OT*
    - Advantages
      - Operating current: 175 μA @ 2V, 4 MHz, typical
      - 14 mm^3 volume
      - 4 I/O pins
      - Internal 4 MHz oscillator
      - Internal comparator
      - Can output 0.6V minimum to 2.7-3V maximum at 3V supply

            - Operating Temp: -40°C to +85°C
        - Disadvantages
            - 1 I/O pin is input-only
            - Output voltage minimum may be too high
    - *PIC10F320-I/OT*
        - Advantages
            - Operating current: 25μA @ 1 MHz, 1.8V, typical
            - Internal 16 MHz oscillator
            - 4 I/O pins
            - Can output 0.6V minimum to 2.7-3V maximum at 3V supply
            - Operating Temp. : -40°C to +125°C
        - Disadvantages
            - 67 mm^3 volume
            - 1 I/O pin is input-only
            - Output voltage minimum may be too high
- **Operational Amplifiers**
    - *ISL28194-95*
        - Advantages
            - 1.8V-5.5V operating range
            - Consumes typically 330nA-1μA of current
            - 1.5mm^3 max volume
        - Disadvantages
            - Single op-amp chip
            - Enable pin on chip must be taken into account
    - *AD8609*
        - Advantages
            - 1.8V-5.5V operating range
            - Available in dual and quad op-amp chips
            - 60μA maximum supply current per amplifier
        - Disadvantages
            - Consumes approximately 55mm^2 board space if quad chip
            - Outputs approximately 5V (PIC input high would be 3V)
    - *AD8235*
        - Advantages
            - Designed for medical instrumentation application
            - 40μA maximum supply current
            - 6nA shutdown current
            - Low-power heart rate monitor application information on datasheet
            - 1.8V-5.5V operating range
            - Available in 1.5 mm × 2.2 mm packaging
        - Disadvantages

        - Uses ball-grid array packaging - difficult to debug
        - Single op-amp chip for our operating voltage
  - *AD622ARZ-ND*
    - Advantages
      - Max input bias current ~5nA
      - 3.5mm width
      - Capable of low input voltage (3V)
    - Disadvantages
      - ±15 V typical operating voltage
      - 900μA supply current
      - $5.92 for 1
  - *NJM2140R-TE1CT-ND*
    - Advantages
      - ±1-7V operating range
      - 3mm width
    - Disadvantages
      - Unknown price on Digikey
      - Not high precision
- **Analog-to-Digital Converters**
  - *MAX1106*
    - Advantages
      - 2.5V-3.6V operating voltage
      - 96μA typical operating current at +3V
      - 8 bit (PIC is 8 bit)
      - Available in package with footprint 20% the size of a plastic 8-pin DIP
    - Disadvantages
      - 20μA maximum input current
      - 250μA Supply maximum (lower would be better)
  - *AD7789*
    - Advantages
      - 2.5V-5.25V operating voltage
      - 75μA maximum supply current
      - Simultaneous 50Hz-60Hz rejection
      - Internal clock
      - $6.86 for 1
    - Disadvantages
      - 24 bit (PIC is 8 bit)
      - 16.6Hz nom update rate
      - AD7789 is cheaper, but has lower update rate
  - *AD7787*

            - Advantages
                - 2.5V-5.25V operating voltage
                - 75µA maximum supply current
                - Simultaneous 50Hz-60Hz rejection
                - Internal clock
            - Disadvantages
                - 24 bit (PIC is 8 bit)
                - $9.23 for 1
                - AD7789 is cheaper, but AD7787 has max 120Hz update rate
- **Leads**
    - *WIRE WW 30AWG WHITE 7" 50PC/PK 30-W-50-050 on Digikey*
        - Advantages
            - .25mm diameter
            - Faster turnaround time from Digikey
        - Disadvantages
            - .25mm diameter may be too large
            - Must design wire to prevent issues such as inductive coupling
    - *Precision Wire Components distribution company*
        - Advantages
            - Expert and professional lead design
            - Customizable lead design
        - Disadvantages
            - Unknown cost
            - Unknown turnaround time
            - Reliant on company to manufacture the lead design correctly

Budget:

Part	Cost per unit	Quantity	Total Cost	Digikey Part#	Notes
BR-1225/VCN	1.53	10	15.30	P192-ND	Battery
PIC10F200T-I/OT	0.41	10	4.10	PIC10F200T-I/OTCT-ND	Microcontoller
30-W-50-050	9.65	1	9.65	W7-ND	Wire leads
AD8235	2.84	4	11.36	AD8235ACBZ-P7CT-ND	Instrumentation
AD8609	4.81	4	19.24	AD8609ARUZ-ND	Quad Operational Amplifier
MAX1106	6.67	4	26.68	MAX1106EUB+-ND	A2D Converter
ESD grounding wristband	5.00	4	20.00	-	To handle ESD sensitive parts
CFAL12832D-B	17.58	1	17.58	-	Possible LCD screen for user interface
PCB	5.00/sq. inch	3	5.00	-	Final draft PCB from Dorkbot 1 inch*1 inch

Total Cost: **$128.91**
Total Budget Requested: **$1000.00**

Timeline:
See attached document.

Summary:
The small animal pacemaker will be used to regulate the beating of a heart by using electric pulses that are transported from the body of the device to its leads that are attached to an atrium and a ventricle. These electrodes have the ability to sense the electric signal from the connected area; if the pacemaker detects an inadequate signal, correct pacing voltage can be applied. The pacemaker will control the hearts and act as a cardiovascular research device. To implement this, we will need to use parts that will enable user-programmable voltage generation, signal processing, signal acquisition, battery power, and pacing and sensing capable electrode leads. For the device, we have decided to use the BR-1225/VCN as the battery because of the smaller surface area and longer battery life. The microcontroller we chose is the PIC10F200T-I/OT because of its small size, lower operating current, 4 I/O pins, and 3 volt capability. It will also run off generally the same software we would use for our benchtop model. For the instrumentation amplifier, we decided on the AD8235 because of its size, lower current needs, and its use in medical devices. We chose the AD8609 because it contains 4 op-amps on a single chip which reduces the size needed for the circuit. We also chose it because of its low supply voltage and its suggested use in conjunction with the AD8235. For an A-D converter, we chose the MAX1106, because it is an 8 bit converter which is the same as the PIC we are using and it also has low operating current. For our leads we have decided to use the 30-W-50-050. We believe that the leads may be too large for the application, so we have allowed ourselves more room in our budget in case we need to change the lead approach. All of our parts would be capable of the 3 volt rated voltage generated by the BR-1225/VCN battery. In our preliminary designs, we may not use these parts, but intend to in our final design.